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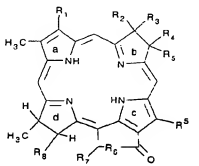
(71) Applicant: **HEALTH RESEARCH, INC.**
Buffalo New York 14263 (US)

(72) Inventors:
- **Pandey, Ravindra K.**
  Williamsville, NY 14221 (US)
- **Grossman, Zachary**
  Buffalo, NY 14209 (US)
- **Kanter, Peter**
  E. Aurora, NY 14052 (US)
- **Dougherty, Thomas J.**
  Grand Island, NY 14072 (US)

(74) Representative: **Weber, Dieter, Dr. et al**
Weber, Dieter, Dr.,
Seiffert, Klaus, Dipl.-Phys.,
Lieke, Winfried, Dr.,
Gustav-Freytag-Strasse 25
65189 Wiesbaden (DE)

(54) Chlorin and bacteriochlorin-based aminophenyl DTPA and N2S2 conjugates for MR contrast media and radiopharmaceuticals

(57) Compositions that are chemical combination of porphyrins, chlorins, bacteriochlorins, and related tetra-pyrrolic compounds with radioactive elements such as Technetium^{99}, Gadolinium, Indium^{111} and radioactive iodine. When the element can form cations, the compound is usually a chelate with the porphyrin or chlorin structure. When the element forms anions, the compound is usually a direct chemical combination of the radioactive element into the porphyrin or chlorin structure. The invention further includes the method of using the compounds of the invention for diagnostic imaging of hyperproliferative tissue such as tumors and new blood vessel growth as is associated with the wet form of age related macular degeneration and methods of making the compounds. Compounds for MRI contrast imaging of the invention are usually Tc^{99}, In^{111} or Gd(III) complexes of compounds of the formula:



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Description

BACKGROUND OF THE INVENTION

[0001] This application claims priority from Provisional Patent Application No. 60/171,961 filed December 23, 1999.

[0002] Cancer is the second most common cause of death in the United States, accounting for 20% of all deaths. Until now, medicine has tried to overwhelm the cancer cell with brute force, slicing it out with surgery, zapping it with radiation, or poisoning it with chemotherapy. All too often, however, a few cells survive the onslaught and germinate, sometimes years later, into tumors that are impervious to treatment. If tumors can be diagnosed at early stages, it will certainly increase the survival rate of the cancer patients. Therefore, efforts are currently underway in our and various other laboratories to develop efficient tumor diagnostic imaging agents.

[0003] For many years, *in vivo* imaging of human anatomy was dependent upon the intravenous administration of radioactive atoms (nuclear medicine) or non-radioactive iodinated contrast media (various x-ray tests and computed tomography). However, over the last decade magnetic resonance imaging (MRI) has assumed a critical role in imaging, and, unlike x-rays or computed tomography, MR uses contrast media that contain paramagnetic ions, particularly Gadolinium [Gd(III)]. Paramagnetic ions are not themselves "seen" by the MR scanner. Rather, they affect the water in body tissue so as to increase the "signal" emitted by tissue when it is placed in a magnetic field.

[0004] By and large, MR contrast media have been neither disease-specific nor organ-specific. Injected intravenously, most are rapidly excreted by the kidneys by glomercular filtration. Although several liver-specific contrast media have been created, other organs have not been successfully targeted, and no tumor-avid MR contrast agents are available to date.

[0005] Because of the importance of detection of unknown primary tumor and metastatic disease in diagnostic oncology imaging, a tumor-avid MR contrast medium would have high implications for prognosis, therapy selection, and patient outcomes. The entire issue of cure versus palliation would be impacted.

[0006] In recent years several reports focused on certain Gd-based macrocycles as potential magnetic resonance imaging (e.g. Z.D. Grossman and S.F. Rosebrough, Clinical Radioimmunoimaging, *Grune & Stratton Inc.*, 1988, incorporated herein by reference as background art) and ^{99m}Tc or ^{111}In chelated compounds as radiopharmaceuticals (e.g. H.D. Burns, R.F. Gibson, R.F. Dannals and P.K.S. Siegel (Eds.): Nuclear imaging in Drug Discovery, Development and Approval, *Birkhauser,* 1993, and G.B. Saha, Fundamentals of Nuclear Pharmacy, *Springer-Verlag,* 1992, incorporated herein by reference as background art).

[0007] Since the approval of $[Gd(DTPA)(H_2O)]^{2-}$ in 1988, more than 30 metric tons of Gadolinium have been administered to millions of patients worldwide. Approximately 30% of MRI exams include contrast agents, and this percentage is projected to increase as new agents and applications appear. Gadolinium is also finding a place in medical research. Over 600 references to Gadolinium appear each year in the basic science literature. While other types of MRI contrast agents, namely an iron-particle-based agent and a manganese (II) chelate have been approved, Gd(III) remains the dominant material. The reasons for this include the direction of MRI development and the nature of Gd chelates. The signal intensity in MRI stems largely from the local value of the longitudinal relaxation rate of water protons, $1/T_1$, and the transverse rate $1/T_2$. Signal tends to increase with increasing $1/T_1$ and decrease with increasing $1/T_2$. Pulse sequences that emphasize changes in $1/T_1$ are referred to as $1/T_1$-weighed, and the opposite is true for T_2-weighed scans. Contrast agents increase both $1/T_1$ and $1/T_2$ to varying degrees, depending on their nature as well as the applied magnetic field. Agents such as Gadolinium (III) that increases $1/T_1$ and $1/T_2$ by roughly similar amounts are best visualized using T_1-weighted images, because the percentage change in $1/T_1$ in tissue is much greater than that in $1/T_2$. The longitudinal and transverse relaxivity values r_1 and r_2 refer to the increase in $1/T_1$ and $1/T_2$, respectively, per millimole of agent. T_1 agents usually have r_2/r_1 ratios of 1-2, whereas that value for *T2* agents, such as iron oxide particles, is as high as 10 or more. Advances in MRI have strongly favored T_1 agents and thus Gadolinium (III). Faster scans with higher resolution require more rapid radio frequency pulsing and are thus generally T_1-weighed, since the MR signal in each voxel becomes saturated. T_1 agents relieve this saturation by restoring a good part of the longitudinal magnetization between pulses. At the same time a good T_1 agent would not significantly affect the bulk magnetic susceptibility of the tissue compartment in which it is localized, thus minimizing any inhomogeneities which can lead to image artifacts and/or decreased signal intensity.

[0008] The other important and interesting characteristic of Gadolinium (III) chelates is their stability. They remain chelated in the body and are excreted intact. For example, the off-the shelf ligands like DTPA form complexes so stable that while the agent is *in vivo*, there is no detectable dissociation. Owing to their large size, lanthanides tend to favor high coordination number in aqueous media. Currently, all Gd(III)-based chelates approved for use in MRI are nine-coordinate complexes in which the ligand occupies eight binding sites at the metal center and the ninth coordinate site is occupies by a solvent water molecule.

[0009] Radiopharmaceuticals are drugs containing a radionuclide and are used routinely in nuclear medicine department for the diagnosis or therapy. Radiopharmaceuticals can be divided into two primary classes: Those whose bio-

distribution is determined exclusively by their chemical and physical properties (like iodine-131) and those whose ultimate distribution is determined by their biological interactions (like a radiolabeled antibody). The latter class includes more target-specific radiopharmaceuticals. A target-specific radiopharmaceutical consists of four parts: a targeting molecule, a linker, a chelating ligand and a radionuclide. The targeting molecule serves as the vehicle, which carries the radionuclaide to the target sita in diseased tissue. The radionuclide is the radiation source.

[0010] Metallic radionuclides offer many opportunities for designing new radiopharmaceuticals by modifying the coordination environment around the metal with a variety of chelators. Most of the radiopharmaceuticals used in conventional nuclear medicine are ^{99m}Tc labeled, becausa of its short half-life (6 hours) and ideal gamma emission (140 KeV). Millicurie quantities can be delivered without excessive radiation to the patient. The monoenergetic 140-KeV photons are readily collimated, producing images of superior spatial resolution. Furthermore, ^{99m}TC is readily available in a sterile, pyogen-free, and carrier-free state from ^{99}MO-^{99m}TC generators. Its 6h half-life is sufficiently long to synthasize the labeled radiopharmaceuticals, assay for purity, inject the patient, and image yet short enough to minimize radiation dose. Another radionuclide successfully used is ^{111}In. The success of the pharmaceutical IN-DTPA-Octreotide (OCTREOSCAN), usad for diagnosis of somatostatin receptor-positive tumors, has intensified the search for new targat-specific radiopharmaceuticals. Compared to ^{99m}Tc, the half-life of ^{111}In is much longer (72 hours).

[0011] Certain porphyrins and related tetrapyrrolic compounds tend to localize in malignant tumors and other hyperproliferative tissue, such as hyperproliferative blood vessels, at much higher concentrations than in normal tissues, so they are useful as a tool for the treatment of various type of cancers and other hyperproliferative tissue by photodynamic therapy (PDT) (T.J. Dougherty, C.J. Gomer, B.W. Henderson, G. Jori, D. Kessel, M. Kprbelik. J. Moan, Q. Peng, *J Natl. Cancer Inst.*, 1998, 90, 889 incorporated here by reference as background art). However, most of the porphyrin-based photosensitizers including PHOTOFRIN® (approved worldwide for the treatment of tumors) clear slowly from normal tissue, so patients must avoid exposure to sunlight for a significant time after treatment. In recent years, a number of chlorophyll analogs have been synthesized and evaluated for their use as photosensitizers for PDT (e.g. R.K. Pandey, D. Herman, *Chemistry & Industry,* 1998, 739 incorporated herein by reference as background art). Among these photosansitizers, the hexyl ethar derivative of pyropheophorbide-a **9** (HPPH) (e.g. R.K. Panday, A.B. Sumlin, S. Constantine, M. Aoudia, W. R. Potter, D.A. Bellnier, B.W. Henderson, M.A. Rodgers, K.M. Smith and T. J. Dougherty, *Photochem. Photobiol.*, 1996, 64, 194; B.W. Henderson, D.A. Bellnier, W.R. Graco, A. Sharma, R.K. Panday, L.A. Vaughan, W.R. Weishaupt and T. J. Dougherty, *Cancer Res.*, 1997, 57, 4000; and R. K. Panday, T.J. Dougharty, *U.S. Patent,* 1993, 5,198,460; *U.S. Patent,* 1994, 5,314,905 and *U.S. Patent,* 1995, 5,459,159, incorporated herein by reference as background art) and the hexyl-ether derivative of purpurin-18-*N*-hexylimide **10** (e.g. R.K. Pandey, W.R. Potter and T.J. Dougharty, *U.S. Patent,* 1999, 5,952,366, incorporated herein by reference as background art) have shown high tumor uptake and minimal skin phototoxicity compared with PHOTOFRIN®. HPPH is currently in phase I/II clinical trials for treatment of various types of cancer by photodynamic therapy at the Roswell Park Cancer Institute, Buffalo, NY and the results are promising.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Figure 1 shows an MR image control using a commercially available contrast agent vs. no use of contrast enhancement agent. The tumor area of the images shows little or no enhancement using the commercially available contrast agent.

[0013] Figure 2 shows the MR image using a Gd-HPPH contrast agent of the invention vs. no contrast agent. The image formed using the contrast agent of the invention shows dramatic image enhancament of tha tumor area.

[0014] Figure 3 is a graph of *in vivo* measurement of tumor vs. muscle uptake by reflection spectroscopy of the compound shown in Figure 3.

[0015] Figura 4 is a schematic diagram showing chemical synthesis of 4-aminophenyl DTPA penta-tert-butyl esters.

[0016] Figure 5 is a schematic diagram showing chemical synthesis of carboxy 3-(hexyloxy)ethyl pyropheophorbide-a from methylpheophorbide-a.

[0017] Figure 6 is a schematic diagram showing chemical synthesis of HPPH-aminophenyl DTPA from carboxy 3-(hexyloxy)ethyl pyropheophorbide-a and 4-aminophenyl DTPA penta-tert-butyl ester followed by reaction with Gadolinium (III) trichloride to form HPPH-aminophenyl DTPA.

[0018] Figure 7 is a schematic diagram showing chemical synthesis of purpurin-18-imide-Gd(III) aminophenyl DTPA (16).

[0019] Figure 8 is a schematic diagram showing preparation of Gd(III) aminophenyl DTPA complex from purpurin 7.

[0020] Figure 9 is schematic diagram showing preparation of bacteriochlorin based Gd(III) aminophenyl DTPA.

[0021] Figure 10 is a schematic formula for bisaminoethanethiol compound 23.

[0022] Figura 11 is a schematic formula for bisaminoathanethiol compound 24.

[0023] Figure 12 is a schematic diagram showing preparation of HPPH based bisaminoethanethiol conjugate 27.

[0024] Figure 13 is a schematic diagram showing preparation of HPPH based In Aminophenyl DTPA conjugate 28.

[0025] Figure 14 is a schematic diagram showing preparation of N_2S_2 ligand ^{99m}Tc complex, Aminophenyl DTPA ^{111}In complex and Aminophenyl DTPA Gd(III) complex, e.g. 3-devinyl-3-(1'-alkoxy ethyl)-17-[3'-(4"-amidobenzyl gadolinium (III)DTPA)]ethyl pyropheophorbide-a, from a DTPA or N_2S_2 dihydro tetrapyrrole compound of the invention.

[0026] Figure 15 is a schematic diegram showing N_2S_2 ligand ^{99m}Tc complex, Aminophenyl DTPA "In complex, and Aminophenyl DTPA ^{111}In Complex, and Aminophenyl DTPA Gd(III) complex. e.g. purpurin-18-(30devinyl-3-(4"-amidobenzyl gadoliniumDTPA)]-N-substituted imide, from a DTPA or N_2S_2 dihydro tetrapyrrole compound of the invention.

[0027] Figure 16 is a schematic diagram showing N_2S_2 ligand ^{99m}Tc complex, Aminophenyl DTPA "In complex, and Aminophenyl DTPA ^{111}In Complex, and Aminophenyl DTPA Gd(III) complex, e.g. purpurin-18-(3-devinyl-3-((l'alkoxy ethyl)-17-[3'-(4"-amidobenzyl gadolinium(III)DTPA)]ethyl pyropheophorbide-a, from a DTPA or N_2S_2 dihydro tetrapyrrole compound of the invention.

[0028] Figure 17 is a schematic diagram showing N_2S_2 ligand ^{99m}Tc complex, Aminophenyl DTPA "In complex, and Aminophenyl DTPA ^{111}In Complex, and Aminophenyl DTPA Gd(III) complex, e.g. bacteriopurpurin 18-3-(alkyl or alkoxyalkyl)-7-keto-17-[3'-(4"-amidobenzyl gadolinium(III)DTPA)]-N-substituted imide, from a DTPA or N_2S_2 tetrahydro tetrapyrrole compound of the invention.

BRIEF DESCRIPTION OF THE INVENTION

[0029] The invention includes compositions thet are chemical combination of porphyrins end chlorins and related tetra-pyrrolic compounds with radioactive elements such as Technetium^{99}, Gadolinium, Indium^{111} and radioactive iodine. When the element can form cations, the compound is usually a chelate with the porphyrin or chlorin structure. When the element forms anions, the compound is usuelly a direct chemical combination of the radioactive element into the porphyrin or chlorin structure.

[0030] Exemples of porphyrin and chlorin structures that cen form compounds with radioactive elements, when modified in accordance with the present invention, are for example described in U.S. Patents 5,756,541; 5,028,621; 4,866,168; 4,649,151; 5,438,071; 5,198,460; 5,002,962; 5,093,349; 5,171,741; 5,173,504; 4,968,715; 5,314,905; 5,459,159; 5,770,730; 5,864,035; 5,190,966; and 5,952,366 all of which are incorporated by reference as background art.

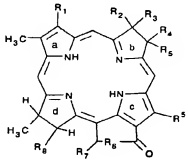
[0031] The invention further includes the method of using the compounds of the invention for diagnostic imaging of hyperproliferative tissue such as tumors and new blood vessel growth as is associated with the wet form of age related macular degeneration.

[0032] Unexpectedly, porphyrins and chlorins, as above described, upon injection, carry the radioactive element into cells of hyperproliferative tissue and dramatically enhance the signal produced by tumor tissue in MR imaging.

[0033] It is to be understood that porphyrin and chlorin compounds (including bacteriochlorins) may be chemically altered to other forms by substitutions and modifications; provided that, the base tetrapyrrolic structure that allows selective entry and retention in hyperproliferative tissue cells (e.g. tumors) is retained.

Compounds of the invention usually have the formula

[0034]



In the above formula,

$R_1 =$  ;

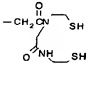
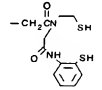
$(CH_2)_2CONH$phenylene CH_2DTPA,

or

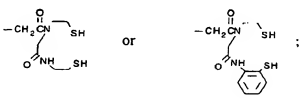
where $R_9 = -OR_{10}$ where R_{10} is lower alkyl of 1 though 6 carbon atoms; R2 is $-CH_3$, R_5 is $-CH_2CH_3$, and R_3 and R_4 together form a covalent bond or R_2 and R_3 together are = 0, R_4 is $-CH_2CH_3$ and R_5 is $-CH_3$; R_6 is

or a covalent bond; R_7 is = O when R_6 is

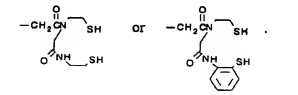
and R_7 is a covalent bond; and R_8 is $-(CH_2)CO_2CH_3$, $-(CH_2)_2CONH$phenyleneCH_2DTPA,

 or 

R_{11} is lower alkyl of 1 through 6 carbon atoms, $-(CH_2)_2CONH$phenyleneCH_2DTPA,



provided that only one of R_1, R_8 or R_{11} is -$(CH_2)_2$CONHphenyleneCH$_2$DTPA,



DETAILED DESCRIPTION OF THE INVENTION

[0035] An objective of the invention was to use these photosensitizers as a vehicle for delivering the desired conjugate (chelated with Gd or radionuclides) to tumor. The chelate is "bifunctional" because, it binds the Gd at one end and binds the target specific vehicle at the other. The chelate is a multidentate ligand, which has appropriate ligating groups for coordination to the metal. In a preferred embodiment, our invention includes:

Development of chlorin and bacteriochlorin-based Gd(III)eminophenyl DTPA conjugates with variable lipophilicity as tumor diagnostic agent by MRI.

Development of chlorin and bacteriochlorin-based ^{111}In aminophenyl DTPA and ^{99m}Tc N_2S_2 conjugates with variable lipophilicity as tumor diagnostic radiopharmaceuticals.

[0036] A goal has been: (i) to successfully bind Gadolinium to a tumor-avid porphyrin, originally designed for photodynamic therapy (PDT), and to prove that striking tumor uptake at 24 hours enhances the "signal" produced by tumor, thus dramatically increasing its conspicuity on MR imaging and (ii) to prepare related ^{99m}Tc and ^{111}In labeled radiopharmaceuticals as diagnostic agents for nuclear medicine.

[0037] This invention includes the synthesis and application of certain chlorin and bacteriochlorin-based bisaminoethanethiol (N_2S_2) and modified ditetratriethylamine penta carboxylic acid (DTPA) conjugates as MR contrast media and radiopharmaceuticals for diagnosis of primary malignancy and metastatic diseases.

The following examples describe examples for synthesis and use of magnetic resonance imaging agents. ***Synthesis of HPPH-Gd(III)aminophenylDTPA*** **14**: For the preperation of the title compound, pyropheophorbida-a **6b** was obtained from methylpheophorbide-a **6a** (which in turn was extracted from *Spirulina Algae)* by following the literature procedure. It was then converted into methyl 3-(hexyloxy)ethyl analog 9a by following a methodology developed in our laboratory. Hydrolysis of the methyl ester functionality with aqueous LiOH/methanol/THF produced the corresponding carboxylic acid 9b in quantitative yield. The reaction of 9b with 4-aminophenyl DTPA penta-*tert*-butyl esters prepared by following the methodology in Figure 4 *via* the carbodiimide approach (R.K. Pandey, F.-Y. Shiau, A.B. Sumlin, T.J. Dougherty and K.M. Smith, *Bioorg. Med. Chem. Lett.*, 1994, 4, 1263, Incorporated herein by reference as background art) produced the corresponding analog 12 in 57% yield (Figures 5 and 6). The structure was confirmed by NMR and mass spectrometry analyses.

[0038] Before preparing the Gd(III) complex, the tert-butyl groups in conjugate were converted into corresponding carboxylic acid by reacting with trifluoroacetic acid (yield 100%). For the preparation of Gd(III) complex 14, the conjugate was dissolved in pyridine and Gadolinium chloride hexahydrate dissolved in deionized water. The mixture was stirred at room tamperature for 2h. After the completion of the reaction (monitored by TLC), pyridina was removed under high vacuum. The residue was washed with water to remove the excess of Gadolinium chloride, dried under vecuum and the title compound was isoleted in 92% yield. The structure of the final product was confirmed by mass spectrometry. *Synthesis of Purpurin-18-imide-Gd(III)aminophenylDTPA 16: Methylpheophorbide-a 7a* was converted into the hexylether derivative of N-hexyl purpurinimide in 70% yield. The methyl ester group was then hydrolyzed to the corresponding cerboxylic acid 10 by following the methodology as discussed for the preperetion of 9b. Purpurin-imide 10 was then

reacted with aminophenylDTPA penta tert-butyl ester 5 by following a reaction sequence depicted in Figure 7 and the intermediate conjugate was isolated in 45% yield. Further reaction with trifluoroaceticacid and then with $GdCl_3.6H_2O$ produced the Gd(III) complex 16 in >90% yield. The structures of the conjugates were confirmed by NMR and mass spectrometry.

[0039] In our attempt to investigate the effect of the position of the Gd(III) conjugate in the macrocycle, purpurinimide 7 was converted into the related carboxylic acid analog 11 by conventional procedures. Reaction of 10 with aminophenyl DTPA 5 will produce Gd(III) aminophenyl DTPA conjugate 15, purpurin 18-3-devinyl-3[4'-emidophenyl Gadolinium (III) DTPA]-N-hexylimide.

[0040] In this series of compounds, the overall lipophilicity of the molecule can be altered by varying the length of the carbon chain of either the alkyl ether substituents and/or *N*-substituted alkyl chain. Thus, these compounds provide a unique opportunity to investigate the correlation of tumor upteke and lipophilicity.

Synthesis of Bacteriochlorin basedGD(III)aminophenylDTPA 22:

[0041] Bacteriochlorins are a class of tetrapyrroles in which the two pyrrole units diagonal to each other are reduced. Starting from N-hexyl-purpurin imide 7 we have prepared ketobacteriochlorin 20 by following a reaction sequence illustrated in Figure 9. In our approach purpurinimide 7 containing a vinyl group at position 3 was converted into the 3-devinyl-3-ethyl analog 17 (also be named as meso-N-hexyl-purpurin-18-imide) by reacting with hydrogen using Pd/C as a catalyst. It was then reacted with osmiumtetroxide/pyridine/H_2S (A.N. Kozyrev. T.J. Dougherty and R.K. Pandey, *Tetrahedron Lett.*, 1996, 37, 3781, incorporated herein by reference as background art) and the corresponding vic-dihydroxybacteriochlorin 18 was isolated in 75% yield as a mixture of diasteriomers (*cis*-hydroxy groups up or down relative to *trans*-reduced ring D). The dihydroxy analog as a diasteriomeric mixture was treated with sulfuric acid under pinacol-pinacolone reaction conditions, (R.K. Pandey, T. Tsuchida, S. Constantine, G. Zheng, C. Medforth, A Kozyrev, A. Mohammad, M.A.J. Rodgers, K.M. Smith and T.J. Dougherty, *J. Med. Chem.*, 1997, 40, 2770, incorporated herein by reference as background art) and the ketobacteriochlorin, containing keto- group either at 7- (compound 20) or 8-position (compound 19) respectively were isolated in 70% yield. Among these bacteriochlorins, the 7-keto analog 20 showed high tumor uptake as determined by *In vivo* reflectance spectroscopy in mice model transplanted with RIF tumor (see Figure 3). The structures of bacteriochlorins 19 and 20 were confirmed by NMR and mass spectrometry analyses.

[0042] Our next step was to hydrolyze the methyl ester group in purpurinimide 20 into carboxylic ecid 21 before converting it into the corresponding 4-aminophenylDTPA conjugate 22 by following the methodology discussed previously for the preparation of related HPPH and purpurin-imide analogs.

[0043] *Synthesis of HPPH-besed Bisaminoethanethiol conjugates 27*: For preparing the ^{99m}Tc labeled radiopharmaceuticals, two aminobisethanethiols 23 and 24 were prepared by following the methodology developed in our laboratory (G. Li, Q. Ma, B. Ma, Z.D. Grossman and R.K. Pandey, *Heterocyclics*, 1999, in press; and G. Li, B. Me, J.R. Missert, Z.D. Grossman and R.K. Pandey, *Heterocyclics*, in press, incorporated herein by reference as background art). For the synthesis of N_2S_2 conjugate 26, HPPH was reacted with N_2S_2 chelate 23 and the thioprotected HPPH conjugate 25 was isolated in 40% yield. Subsequent deprotection of the thiols with triethysllane/TFA afforded the corresponding bisaminoethanethiol 26 in quantitative yield. The structure of the newly synthesized compound was confirmed by NMR and mass spectrometry analyses.

[0044] The Tc-99m complex 27 was prepared by ligand-exchange reaction with ^{99m}Tc pertechnatete reduced by Sn (II)glucoheptonate by following the methodology of Kung and coworkers (S.K. Meegalla, K. Plossl, M-P. Kung, S. Chumpradit, D.A. Stevenson, S.A. Kushner, W.T. McElgin, P.D. Mozley end H.F. Kung. J. *Med. Chem.*, 1997, 40, 9, incorporated herein by reference as background art). The radiolabeling yield was >80%. The purity of the Tc-99m complex was >95%, by chromatography.

Syntheses of HPPH besed ^{111}In AminophenylDTPA conjugate 28: For the preparation of the title compound, the HPPH-aminophenylDTPA 13 was reacted with ^{111}In(III) chloride, following the methodology reported by Low and coworkers (S. Wang J. Juo, D.A. Lantrip, D.A. Waters, C.J. Mathias, W.A. Green, P.L. Fuchs and P.S. Low, *Bioconjugate Chem.*, 1997, 8, 673, incorporated herein by reference es background ert) for the preparation of ^{111}In DTPA-Folate and the ^{111}In labeled compound was obtained in 82% yield.

Body Tumor MR Imaging:

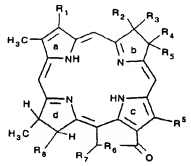
HPPH-Gd(III)AminophenylDTPA conjugate 14:

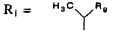
[0045] Following the synthesis of GD-labeled HPPH, a series of three rats were injected intravenously and studied immediately after injection, at 1 hour, and at 24 hours, to establish whether the Gd-HPPH remained in the circulation longer than the current stenderd contrast medium (Magnavist or Gd-DTPA).

[0046] Whereas Magnavist clears rapidly from the mammalian circulation by glomerular filtration, with a circulatory half-time of 16-20 minutes, the newly-synthesized contrast medium Gd-HPPH, was evident in the cerebral circulation at 1 hour. Subsequently, to establish whether the GD-HPPH is tumor-avid, a single rat with a subcutaneously-implanted Ward colon carcinoma was imaged, 24 hours after intravenous GD-HPPH. A second tumorbearing rat was imaged 24 hours after injection of Magnavist (See Figures 1 and 2). Clearly, the enhanced tumor signal after Gd-HPPH injection indicated that GD-HPPH 14 has potential as a contrast medium for MR. HPPH (a chlorophyll- a derivative) represents the vehicle by which the Gd complex is carried into the tumor. Addition of the Gd chelate to HPPH does not hinder its ability to form singlet oxygen producing efficacy, so this contrast medium also has the potential for dual action: enhanced localization on MR imaging (diagnosis), followed by directed light exposure with tumor injury (treatment). Also, because of its excellent tumor selectivity and high fluorescence, the newly synthesized conjugate can be used for IR imaging. Also, Indium or other radionuclides like Tc-99m (the latter conjugated by an N_2S_2 ligand) bound to chlorins and bacteriochlorins synthesized and proposed in this invention have potential as imaging agents for nuclear medicine.

Claims

1. A tetrapyrrole compound characterized in that it has the formula





$-(CH_2)_2CONHphenyleneCH_2DTPA,$

or

where R_9 = -OR_{10} where R_{10} is lower alkyl of 1 though 6 carbon atoms; R_2 is -CH_3, R_3 is -CH_2CH_3, and R_3 and R_4 together form a covalent bond or R_2 and R_3 together are = O, R_4 is -CH_2CH_3 and R_5 is -CH_3; R_6 is

$$-N-$$
$$R_{11}$$

or a covalent bond; R_7 is = O when R_6 is

$$-N-$$
$$R_{10}$$

and R_7 is a covalent bond; and R_8 is -$(CH_2)CO_2CH_3$, -$(CH_2)_2$CONHphenyleneCH$_2$DTPA,


or

;

R_{11} is lower alkyl of 1 through 6 carbon atoms, -$(CH_2)_2$CONHphenyleneCH$_2$DTPA,


or

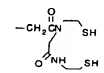
;

provided that only one of R_1, R_8 or R_{11} is -$(CH_2)_2$CONHphenyleneCH$_2$DTPA,

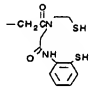

or

.

2. The compound of Claim 1 characterized in that R_1, R_8 or R_{11} is

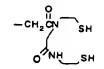


or



3. The compound of Claim 1 characterized in that R_1, R_8 or R_{11} is -$(CH_2)_2$CONHphenyleneCH$_2$ DTPA.

4. The compound of Claim 2 characterized in that R_8 is



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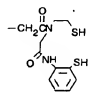

5. The compound of Claim 3 characterized in that R_8 is -$(CH_2)_2$CONHphenyleneCH$_2$DTPA.

6. The compound of Claim 5 characterized in that R_2 is -CH_3 and R_5 is -CH_2CH_3.

7. The compound of Claim 1 characterized in that R_6 is

8. The compound of Claim 7 characterized in that R6 is

where R_{10} is hexyl.

9. A Technetium^{99m} complex of the compound of Claim 2.

10. An Indium^{111} complex of the compound of Claim 3.

11. A Gadolinium(III) complex of the compound of Claim 3.

12. The compound of Claim 9 characterized in that the compound is a ^{99m}Tc bisaminoethanethiol analog of HPPH.

13. The compound of Claim 10 characterized in that the compound is a ^{111}In aminophenyl DTPA analog of HPPH.

14. The compound of Claim 11 characterized in that the compound is HPPH-Gd(III)aminophenylDTPA

15. The compound of Claim 11 characterized in that the compound is purpurin 18 imide-Gd(III)aminophenylDTPA.

16. The compound of Claim 11 characterized in that the compound is a Gd(III)aminophenylDTPA analog of bacteriochlorin.

17. A method for the preparation of the compound of Claim 14 characterized in that it comprises:

hydrolizing methyl 3-(hexyloxy)ethyl pheophorbide a with an aqueous solution of LiOH, methanol and tetrahydrofuran to obtain the corresponding carboxylic acid;
reacting the carboxylic acid with 4-aminophenyl DTPA penta-tert-butyl ester to produce the tert-butyl aminophenyl DTPA analog;
reacting the DTPA analog with trifluoroacetic acid to convert the tertiary butyl groups to carboxylic acid groups;
reacting with a solution of Gadolinium hexahydrate.

18. A method for the preparation of the compound of Claim 15 characterized in that it comprises:

hydrolizing a methyl ester group of the hexylether derivative of N-hexyl purpurinimide to the corresponding carboxylic acid;
reacting the resulting carboxy purpurin imide with a solution of aminophenylDTPA penta-tert-butyl ester;
reacting the resulting conjugate with trifluoroacetic acid to obtain a carboxylic acid; and
reacting the resulting carboxylic acid with Gadolinium chloride to obtain the desired compound.

19. A method for the preparation of the compound of Claim 16 characterized in that it comprises:

hydrogenating 3 vinyl purpurinimide 7 to obtain meso-N-hexyl-purpurin-18-imide;
reacting the meso-N-hexyl-purpurin-18-imide with osmiumtetroxide, pyridine and H_2S to obtain vic-dihydroxybacteriochlorin;
reacting the vic-dihydroxybacteriochlorin with sulfuric acid to obtain a 7-ketobacteriochlorin;
hydrolizing a methyl ester group in the 7-ketobacteriochlorin to a carboxy group;
reacting the carboxy 7-ketobacteriochlorin with aminophenylDTPA penta-tertiary butyl ester;
reacting the resulting product with trifluoroacetic acid to obtain the corresponding carboxylic acid DTPA analog; and
reacting the carboxy DTPA analog with Gadolinium chloride to obtain the desired compound.

20. A method for the preparation of the compound of Claim 12 characterized in that it comprises:

reacting HPPH with aminobisethanethiol to obtain a thioprotected HPPH conjugate;
reacting the conjugate with triethylsilane and TFA to deprotect the thiols; and
reacting the conjugate with deprotected thiols with ^{99m}Tc pertechnatate reduced by Sn(II) glucoheptonate to obtain the desired compound.

21. A method for the preparation of the compound of claim 12 characterized in that it comprises:
reacting HPPH-aminophenylDTPA with ^{111}In(III)chloride to obtain the desired compound.

Fig. 1

Baseline (left) and 24-hour post-injection images (right) of a tumor-bearing rat. Contrast medium was Magnavits - the standard, commercially-available agent. Tumor area of interest "1" revealed no signal enhancement, visually or quantitatively.

Fig. 2

Baseline (left) and 24-hour post-injection images (right) of a tumor-bearing rat. Contrast medium was Gd-HPPH. Area of interest "3" increases markedly, from 623 to 881. The effect is striking both visually as well as quantitatively. Note that the signal enhancement is largely restricted to tumor: fat is unchanged (1998 goes to 1939), and muscle enhancement is minimal

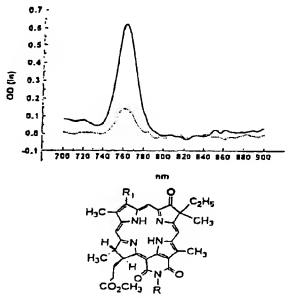

Fig. 3

In vivo measurement of tumor (----) vs muscle (----) uptake by *in vivo* reflection spectroscopy in a mouse bearing a RIF tumor.

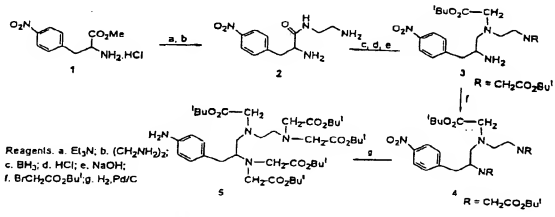

Fig. 4

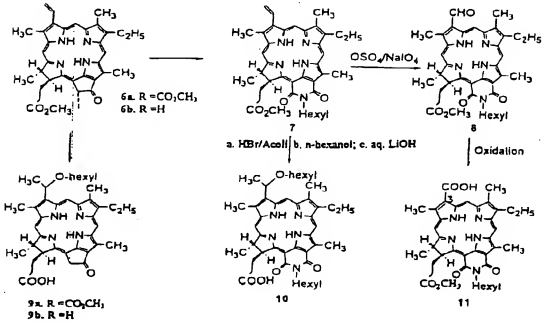

Fig. 5

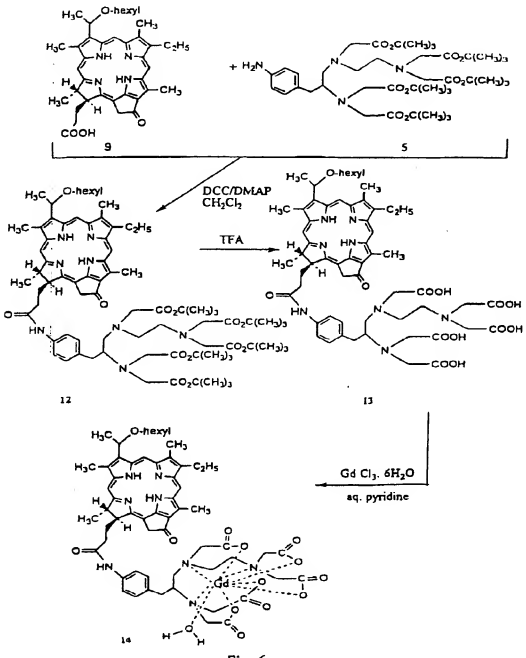

Fig. 6

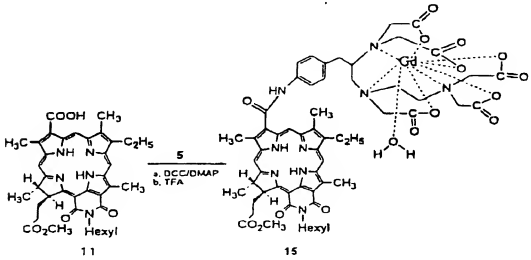

Fig. 7

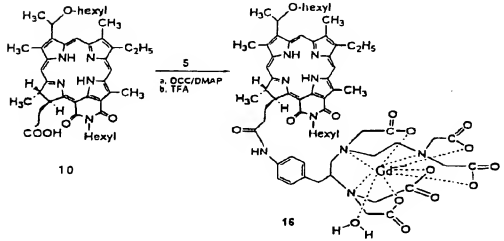

Fig. 8

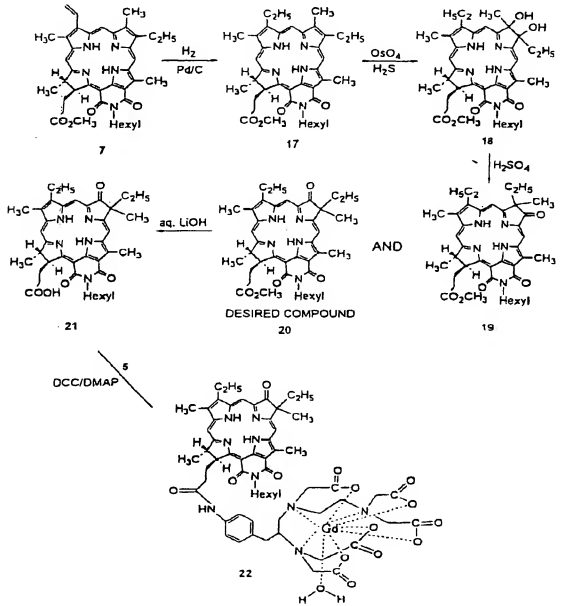

Fig. 9

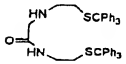

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Fig. 10

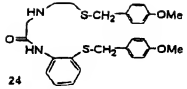

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Fig. 11

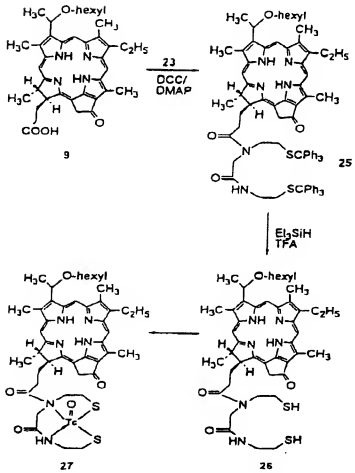

Fig. 12

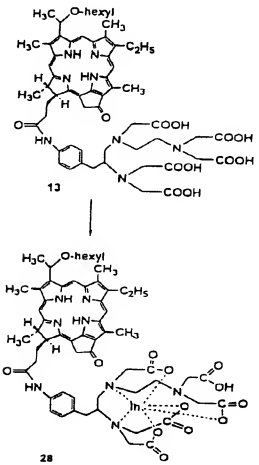

Fig. 13

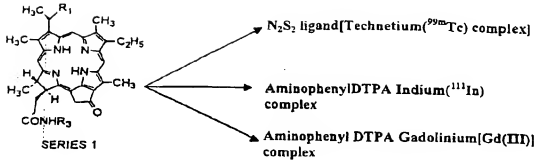

Fig. 14

R_3 = phenyl-CH_2-DTPA or N_2S_2 conjugates
R = -(CH_2)n-DTPA or N_2S_2 conjugates
R and R_1 = Substituents with variable liphophilicity

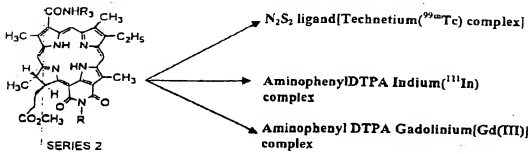

Fig. 15

R_3 = phenyl-CH_2-DTPA or N_2S_2 conjugates
R = -(CH_2)n-DTPA or N_2S_2 conjugates
R and R_1 = Substituents with variable liphophilicity

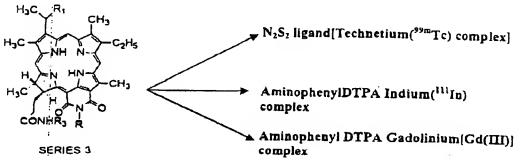

Fig. 16

R_3 = phenyl-CH_2-DTPA or N_2S_2 conjugates
R = -(CH_2)n-DTPA or N_2S_2 conjugates
R and R_1 = Substituents with variable liphophilicity

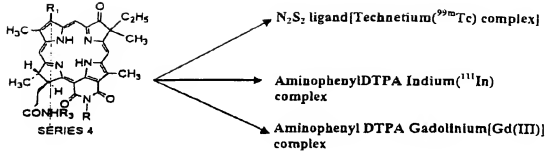

Fig. 17

R_3 = phenyl-CH_1-DTPA or N_2S_2 conjugates
R = -(CH_2)n-DTPA or N_2S_2 conjugates
R and R_1 = Substituents with variable liphophilicity

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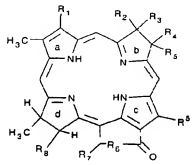
(71) Applicant: **HEALTH RESEARCH, INC.**
Buffalo New York 14263 (US)

(72) Inventors:
- **Pandey, Ravindra K.**
Williamsville, NY 14221 (US)
- **Grossman, Zachery**
Buffalo, NY 14209 (US)
- **Kanter, Peter**
E. Aurora, NY 14052 (US)
- **Dougherty, Thomas J.**
Grand Island, NY 14072 (US)

(74) Representative: **Weber, Dieter, Dr. et al**
Weber, Dieter, Dr., Seiffert, Klaus, Dipl.-Phys., Lieke, Winfried, Dr., Gustav-Freytag-Strasse 25
65189 Wiesbaden (DE)

(54) **Chlorin and bacteriochlorin-based aminophenyl DTPA and N2S2 conjugates for MR contrast media and radiopharmaceuticals**

(57) Compositions that are chemical combination of porphyrins, chlorins, bacteriochlorins, and related tetra-pyrrolic compounds with radioactive elements such as Technetium^{99}, Gadolinium, Indium^{111} and radioactive iodine. When the element can form cations, the compound is usually a chelate with the porphyrin or chlorin structure. When the element forms anions, the compound is usually a direct chemical combination of the radioactive element into the porphyrin or chlorin structure. The invention further includes the method of using the compounds of the invention for diagnostic imaging of hyperproliferative tissue such as tumors and new blood vessel growth as is associated with the wet form of age related macular degeneration and methods of making the compounds. Compounds for MRI contrast imaging of the invention are usually Tc^{99}, In^{111} or Gd(III) complexes of compounds of the formula:



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EUROPEAN SEARCH REPORT

Application Number
EP 00 12 8019

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	PANDEY, RAVINDRA K. ET AL: "Structure/activity relationships among photosensitizers related to pheophorbides and bacteriopheophorbides" BIOORG. MED. CHEM. LETT. (1992), 2(5), 491-6 , XP001030681 * table 1 *	1	C07D487/22 //A61K51/04, A61K49/00, (C07D487/22, 257:00,209:00, 209:00,209:00, 209:00)
A,P	WO 99 67248 A (HEALTH RESEARCH INC) 29 December 1999 (1999-12-29) * claim 2 *	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

C07D
A61K
A61P

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	17 October 2001	Alfaro Faus, I

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17-10-2001

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		EP 1087974 A1	04-04-2001
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